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A Proposal to Fermi National Accelerator Laboratory

Exclusive KN Charge Exchange

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13 pgs

Abstract

We propose a measurement of the reactions $K^-p \to \overline{K^o}\, n$ and $K^+n \to K^op$ at three different incident momenta: 75, 100 and 150 Gev/c. The experiment would utilize the M4 beam and spectrometer now measuring the K^-p inclusive reaction and would require little additions or modifications. We propose to modify the apparatus immediately following the completion of E383, this spring.

B) Physics Justification

The recently published CalTech-LBL measurements of the reactions[1,2]

$$1)\ \pi^- p \to \pi^0 n \qquad \text{and} \qquad 2)\ \pi^- p \to \eta^0 n$$

show that a description of the high energy behavior of these processes is possible in terms of single Regge poles.

Very briefly, they indicate that in accord with the predictions of Regge theory for processes mediated by the exchange of a single pole, the reactions have the simple power law energy dependence at fixed t. To wit:

$$\frac{d\sigma}{dt}(s,t) = \beta(t)\ \nu^{2\alpha(t)-2}$$

where $\nu = (s-u)/4m$.

Moreover the functions α are nearly linear in t with the extrapolation of the ρ trajectory from reaction (1) connecting nicely with the ρ and g masses.

The remarkable success of the simple theory suggests further tests involving reactions in which both of these trajectories are operative, the K charge exchange reactions: $K^- p \to \overline{K^0} n$ and $K^+ n \to K^0 p$.

If we assume in the usual way the standard SU(3) pseudoscalar meson couplings and label the I=1 meson exchange amplitudes of even and odd G parity F(s,t) and D(s,t) respectively, than these relations among the amplitudes follow:[3]

$$\langle \pi^- p | \pi^\circ n \rangle = -\sqrt{2}\, F(s,t)$$

$$\langle \pi^- p | \eta^\circ n \rangle = (2/3)^{1/2}\, D(s,t)$$

$$\langle K^- p | \overline{K^\circ} n \rangle = F(s,t) + D(s,t)$$

$$\langle K^+ n | K^\circ p \rangle = -F(s,t) + D(s,t)$$

ignoring any mass dependent symmetry breaking effects.

The cross sections may be expressed in terms of the F's and D's

$$\frac{d\sigma}{dt}(\pi^- p \rightarrow \pi^o n) \ \alpha \ |F|^2 \ ; \quad \frac{d\sigma}{dt}(\pi^- p \rightarrow \eta^o n) \ \alpha \ |D|^2$$

and

3) $\frac{d\sigma}{dt} (K^- p \rightarrow \bar{K}^o n) \ \alpha \ |F|^2 + |D|^2 + 2ReF^*D$

4) $\frac{d\sigma}{dt} (K^+ n \rightarrow K^o p) \ \alpha \ |F|^2 + |D|^2 - 2ReF^*D$

That the two cross sections (3,4) are not equal, or what is equivalent that the cross-term is non-zero, at low energies has been shown in experiments with kaon beams of up to 13 Gev/c.[4,5,6] These experiments show that reaction (4) is about 1.3 times reaction (3) independent of both t and s. This indicates that the size of the cross-term is about 15% of the averaged cross sections and also gives us an idea of the expected cross section ratio.

That the cross sections differ at these two energies could be dismissed as a low energy arifact not truly representative of high-energy behaviour where exchange degeneracy may dominate. Our experiment would put these ideas to a test at incident momenta exceeding the highest previous by more than a factor of ten.

Should any differences be observed either between the reactions (3) and (4) or with the predictions from (1) and (2) we would expect to extract more detailed information by means of specific formulations based on Regge pole models, poles with cuts, etc.

Inasmuch as the π and K charge exchange reactions depend on only two amplitudes certain sum rules apply. One of interest here is:

5) $\frac{d\sigma}{dt}(K^- p \rightarrow \bar{K}^o n) + \frac{d\sigma}{dt}(K^+ n \rightarrow K^o p) = \frac{d\sigma}{dt}(\pi^- p \rightarrow \pi^o n) + 3\frac{d\sigma}{dt}(\pi^- p \rightarrow \eta^o n).$

If we could assume even the weak form of exchange degeneracy $\alpha_\rho(t) = \alpha_{A2}(t)$, the cross sections for the kaon charge exchange reactions would be equal and each equal to 1/2 of the right hand side of (5).

In rate calculations below we assume the equality of the cross sections 3) and 4) and the results of Ref. 1 and 2 to predict their values.

C) Experimental Method

Figure 1 is a scale drawing of the current E-383 apparatus. Indicated also are counters labelled"CV" which are charged particle veto's,"SC" shower veto's, "BC" baffle counters and "CAL" a calorimeter covering the aperture of the experiment. While none of these are in use in the current experiment, the "CV" and "SC" counters are already installed, the "BC" are on hand and the calorimeter is under construction. The "SC" counters and part of the "BC" have been kindly loaned tu us by members of the CalTech-LBL groups for which we are most grateful.

In order to measure the K^-p charge exchange reactions we will demand no outgoing charged particles in CV_1 through CV_5, in the K^+n this condition will be relaxed permitting one of the CV_1 through CV_4 to fire, thus not vetoing the recoil proton. The proportional chambers PWC 1-2 will be set to trigger on 2 and only 2 outgoing particles and offline analysis of the calorimeter will be performed to eliminate possible gamma rays accompanying the charged K_S decay products.Following the lead of the successful CalTech-LBL efforts software cuts will be appliedto the shower counters surrounding the target,"SC", and baffle counters "BC" to further purify the sample of elastic reactions. Preliminary tests indicate that an adequate degree of trigger suppression is achieved by the above "loose" requirement. The finite resolution of the apparatus ($\Delta p/p \sim 1\%$ for incident particles and $\Delta p/p \sim 2$-3% for outgoing at ~ 100 Gev/c) does not permit accurate reconstruction of the mass of the recoil as a test of the reaction being elastic. Instead it is necessary to place great reliance on the various veto counters to insure that no extraneous particles accompany the desired event. In this respect the experiment will have many of the same problems as CalTech-LBL and we expect to benefit greatly from their experience.

The resolution in t, the momentum transfer squared, has been measured in the current experiment, E-383, and is more than adequate for our intended binning (comparable to CalTech-LBL).

The measurement of the reaction $K^+n \rightarrow K^0p$ involves the use of a deuteron target and presents several complications. The resolut in t from its very definition is unaffected but the resolution in the missing mass is affected. This effect is, however, negligible compared to the apparatus resolution. We have already mentioned above a possible trigger scheme. Its efficacy awaits detailed tests.

D) Rate Estimates

In Table 1 we summarize our rate calculations for 4 incident K^- momenta.

The following assumptions have been used

1) $\sigma_t(K^-p \rightarrow \overline{K^0}n) = \frac{1}{4}\{\sigma_t(\pi^-p \rightarrow \pi^0n) + 3\,\sigma_t(\pi^-p \rightarrow \eta n)\}$

2) Hydrogen target 71 cm long.

3) Decay fraction $\overline{K}^0 \rightarrow K_s = \frac{1}{2}$.

4) Total particle flux through the apparatus less than 2×10^6 particles per pulse.

5) 80% decay probability of the K_s^0 in our apparatus.

6) An acceptance equal to 75% averaged over t.

7) Branching ratio $K_s \rightarrow \pi^+\pi^- \sim 2/3$

The Table includes, for four different beam momenta, the minimum number of protons required on the meson target, the number of K^- on our target, the cross section out to 1.0 Gev^2, and the expected number of events in 100 hours of running with an 8.5 sec. cycle time. In Figure 2 we plot the 150 Gev/c cross-section derived from Refs. 1 and 2. This includes 26,000 events of reaction (1) but only 2500 from reaction (2).

E) Proposed Schedule

E-383 is scheduled to finish running this spring after which we propose an immediate switch over to the exclusive experiment. The rigging involved is minimal but some time will be needed to install the "BC" and to setup the counters "SC", "BC" and "CAL". Barring unforeseen delays this should not take any longer than about two weeks.

F) Time Request

Our request for time is:

P	$K^-p \rightarrow \overline{K}^0 n$	$K^+n \rightarrow K^0 p$
75	100 hours	100 hours
100	100 hours	100 hours
150	100 hours	100 hours
	300 hours	300 hours

Total: 600 hours exclusive of set-up time.

We are aware that accelerators do not always perform as expected. If we run out of time due to the impending mesopause we would favor the K^- running by a factor of 2.

G) Requirements from FNAL

1) The current allotment of PREP funds to E-383.

2) Some rigging help in the tunnel, for instance, our sweeper 4B7 would have to be displaced sideways to make room for the baffles.

3) Beam intensity of $2\text{-}3\times10^{12}$ ppp for 2/3 of the run and $\sim 8\times10^{12}$ for the remainder.

F) <u>Support for the experiment</u>

This experiment like the current e-383 will be supported by an NRC grant to Carleton University and by funds from NSF grants to UCSD and MSU.

In summary, we have constructed a spectrometer and assembled an experimental team well capable of performing these delicate measurements. We feel strongly that the time to do this experiment is now and not some time in the future when it could be difficult to arouse the same enthusiasm in our people to say nothing of the difficulties in reviving equipment. We are confident that because of the physics interest of the experiment and the very modest demands on laboratory resources, the laboratory management will wish to schedule us as soon as possible.

Table 1

P(Gev/c)	Minimum Number Protons on Meson Target	K^- on Tgt.	$\sigma_T(\mu b)$	Ev./100 hrs.
75	2×10^{12}/pulse	64,000/pulse	4.4	7100
100	2×10^{12}	84,000	3.0	6300
125	3×10^{12}	112,000	2.25	6300
150	8×10^{12}	200,000	1.74	8700

Footnotes

1. "Pion Charge Exchange Scattering at High Energies", A. V. Barnes et al., Phys. Rev. Lett. 37, 76 (1976).

2. "Reaction $\pi^- p \rightarrow \eta n$ at High Energies", O. J. Dahl et al., Phys. Rev. Lett. 37, 80 (1976).

3. V. Barger and D. Cline, "Phenomenological Theories of High Energy Scattering", (Benjamin, New York, 1969).

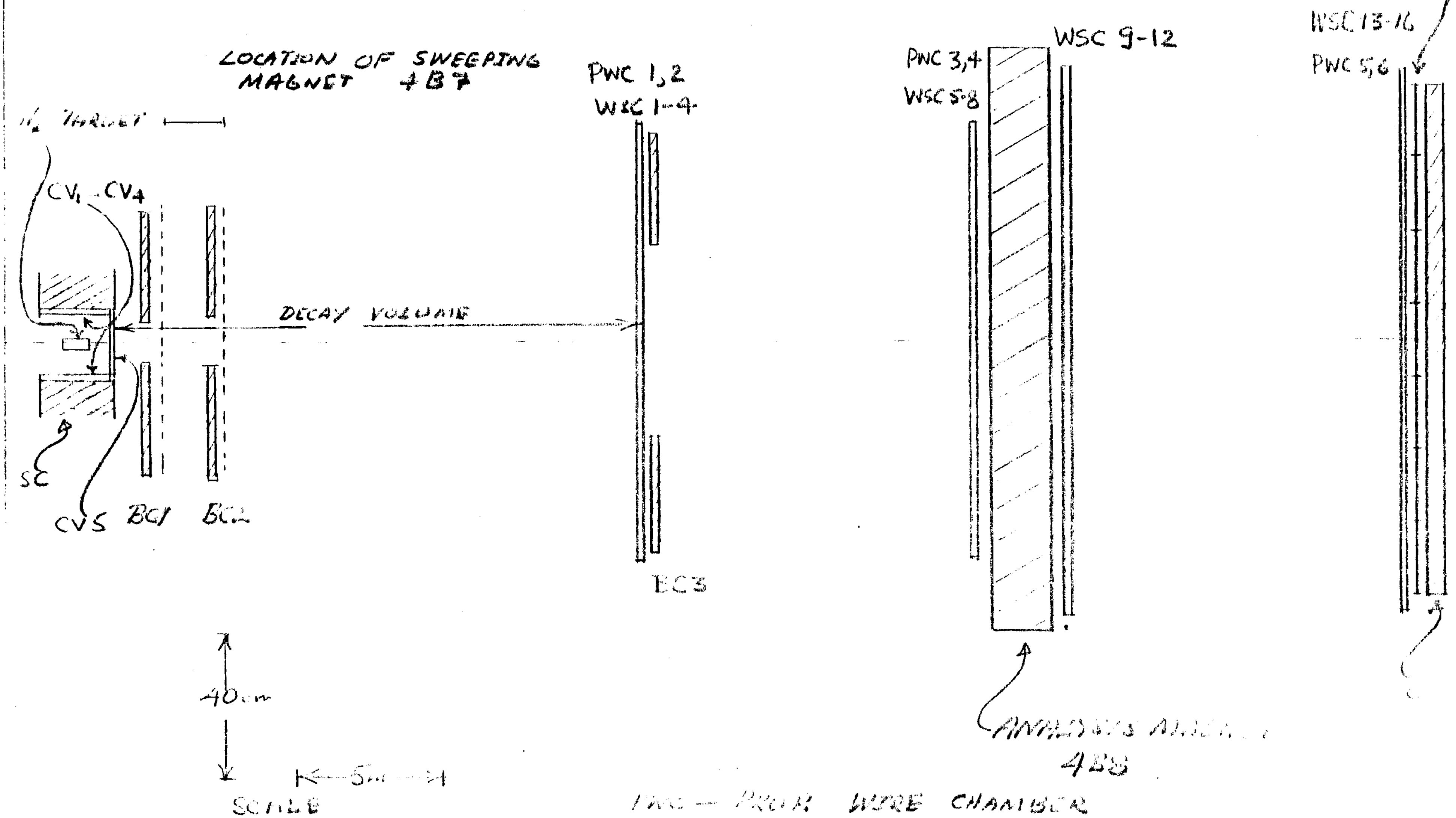
4. R. Diebold et al., Phys. Rev. Lett. 32, 904 (1974).

5. J. J. Phelan et al., Phys. Lett. 61B, 483 (1976).

6. Comparison of $K^{\pm}N$ Charge Exchange Reactions at 8.5 and 13 GeV/c". M. G. D. Gilchriese et al., Phys. Rev. Lett. 40,6 (1978).

FIGURE 1

M-4 SPECTROMETER



PWC — PROP. WIRE CHAMBER
WSC — WIRE SPARK CHAMBER

delete

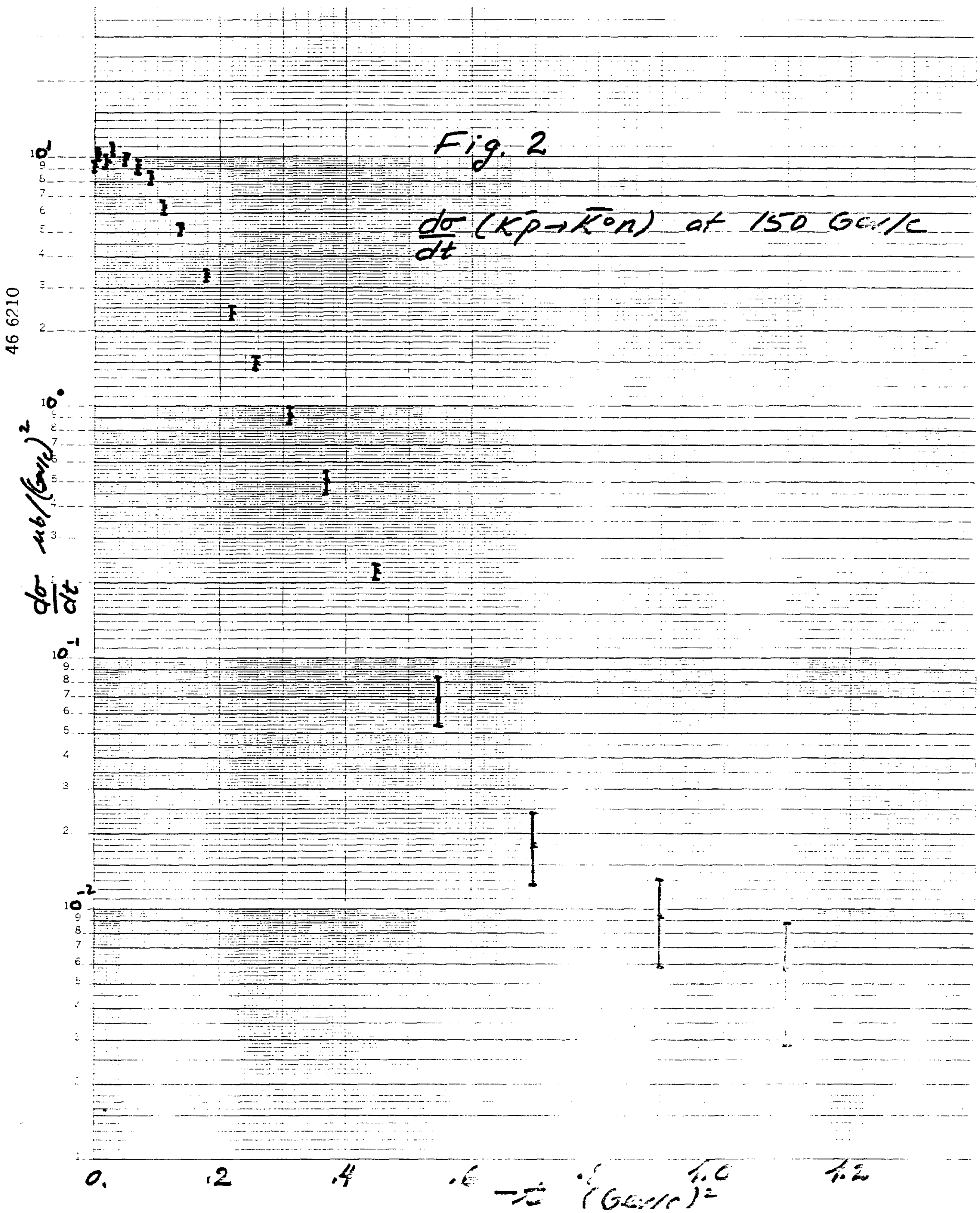


Fig. 2
$\frac{d\sigma}{dt}(K^-p \to \bar{K}^0 n)$ at 150 GeV/c
$\frac{d\sigma}{dt}$ $\mu b/(GeV/c)^2$
10^1
10^0
10^{-1}
10^{-2}
0.
.2
.4
.6
1.0
1.2
$-t$ $(GeV/c)^2$
46 6210

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